SENSATION AND PERCEPTION

a unit lesson plan for high school psychology teachers

Sandra Alvarado, Bonnie Kanter-Braem, Kathleen Manz, Peter Masciopinto, Eileen McKenna, Dana Nelson, Christopher Williams, and Kent Korek
2007 Revision Team

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This unit is a revision of the original TOPSS Unit Lesson Plan on *Sensation and Perception*, written by Nancy Grayson, Kathleen Self, Martha J. Whitacre, and Marvin Ziegler (Randal M. Ernst, Editor) originally prepared at the Texas A&M-NSF Summer Institute for the Teaching of AP and Honors Psychology in July 1992.

This unit is aligned with the following content standards of the *National Standards for High School Psychology Curricula* (APA, 2011):

Standard Area: Sensation and Perception

Content Standards
1. The processes of sensation and perception
2. The capabilities and limitations of sensory processes
3. Interaction of the person and the environment in determining perception

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procedural timeline

Lesson 1: Introduction to Sensation and Perception
Activity 1.1: Sensation: Movement Detectors

Lesson 2: Vision and Audition
Activity 2.1: Distribution of Rods, Cones, and Color Vision in the Retina
Activity 2.2: Blind Spot in Vision
Activity 2.3: Locating Sound Sources

Lesson 3: Other Senses
Activity 3.1: Sensory Interdependencies

Lesson 4: Perception
Activity 4.1: The Stroop Effect

introduction

Sensation and Perception is an area in psychology that is "demonstration-rich." In many cases, there is no need to collect many data points, compute averages, or do statistical testing to determine if an effect occurred. In most situations, the phenomenon can be seen or heard by the students.

Another bonus is that many of the demonstrations are available to teachers on websites. Most websites have decent explanations presented alongside the demonstration (see the Resources section for examples). Nonetheless, reviewing the websites prior to use is essential. Although the demonstrations might be explained well, slight differences could occur. These differences could be confusing to students. Thus, you will want to be sure the explanation is accurate.

LESSON 1 is an overview of sensation and perception. The main purpose of the lesson is to give students the vocabulary for the study of sensation and perception. Lesson 1 connects these concepts to real-life situations such as hearing or vision tests.

LESSON 2 describes the visual and auditory systems. This lesson concerns neuroanatomy, focusing on the eye and ear. It is possible to spice up the presentation by discussing disorders of sensation and perception, such as near- and far-sightedness, color blindness, and some relatively rare brain disorders (e.g., prosopagnosia).

LESSON 3 reviews the other senses (e.g., gustation, olfaction, and somesthesis).

LESSON 4 moves to perception, from the ability to sense a stimulus, to selecting and interpreting the stimulus. Some of the material is historically significant, such as the Gestalt approach, which remains an important set of concepts in contemporary psychology. The role that expectations play on a person's perception is also included.

content outline

LESSON 1: Introduction to Sensation and Perception

OVERVIEW: An important theme in this lesson is that external information gets recoded (transduced) into neural activity. In other words, one type of information (e.g., light energy) is changed into a different type of information (e.g., neural activity in the optic nerve). There are limits on both the types and the amount of external information to which a person is sensitive. It is also important to note that the relationship between the external stimulus (i.e., the nominal stimulus) and the internal representation (i.e., the functional stimulus) is **NOT** one-to-one.

I. Sensation is the process by which we receive information from the environment.

A. What kind of information? A **stimulus** is a detectable input from the environment:

1. Light—vision
2. Sound—hearing
3. Chemicals—taste and smell
4. Pressure, temperature, pain—sense of touch
5. Orientation, balance—kinesthetic senses

B. Environmental information (stimuli) exists in many forms:

1. A physical stimulus must first be introduced. For example: air vibrations, gases, chemicals, tactile pressures

2. Our senses respond to a limited range of environmental stimuli. For example, we cannot hear sound of frequencies above 20,000 Hz, even though dogs can hear them.

C. Some physical stimuli that our bodies are sensitive to:

1. Light as experienced through vision

a. Visible light is part of the electromagnetic spectrum.
b. Properties of light
   i. Intensity (experienced as brightness)
   ii. Wavelength (experienced as hue)
   iii. Complexity or purity (experienced as saturation)

2. Sound as experienced through audition

Properties of sound
   i. Intensity (influences mainly loudness)
   ii. Frequency (influences mainly pitch)
   iii. Wave form (influences mainly timbre)
   iv. As noted above, there is not a one-to-one relationship between physical properties and perceptual experience. For example, intensity can also influence perception of pitch.

D. Sensory processes are the initial steps to perception.

1. **Transduction** is the process of converting energy of a stimulus into neural activity. The stimulus is recoded as a neural pattern.

2. Transduction can be affected by our experiences, such as through **adaptation**; a constant level of stimulus results in a decreased response over time. With continued exposure, the neural response to the stimulus may change. Adaption is also perceptual, not just sensory.

II. Perception is the process of selecting and identifying information from the environment.

A. Perception is the **interpretation** of information from the environment so that we can identify its meaning.

B. Sensation usually involves sensing the existence of a stimulus, whereas perceptual systems involve the determination of what a stimulus is.

C. Expectations and perception: Our knowledge about the world allows us to make fairly accurate predictions about what should be there—so we don't need a lot of information from the stimulus itself.

1. **Bottom-up processes** are processes that are involved in identifying a stimulus by analyzing the information available in the external stimulus.

This also refers to information processing that begins at the receptor level and continues to higher brain centers.

2. **Top-down processes** are processes that are involved in identifying a stimulus by using the knowledge we already possess about the situation. This knowledge is based on past experiences and allows us to form expectations about what we ought to perceive.

    a. This also refers to information processing that begins in higher brain centers and proceeds to receptors.
    b. Top-down processes allow for perceptual judgments and bias to start influencing how we process incoming stimuli and information. Early incoming information is already being processed in terms of top-down influences and previous experience.

III. Psychophysics is the study of the mathematical or functional relationship between physical energy and psychological experience.

For example, how much more intense must a stimulus be in order for us to perceive a change in intensity? Psychophysics tells us that the amount of change needed depends on the initial intensity. A quiet sound needs to be turned up less than a louder sound. *Classroom lights can provide a simple demonstration of this; if the main lights are already on and you add an additional light, perception of brightness changes little. But if you start with the room mostly dark and add the same additional light, there is a large change in perception of brightness.*

A. **Thresholds**

1. **Absolute threshold**

    a. The point at which a stimulus can be detected 50 percent of the time
    b. Given a particular stimulus, the minimum stimulation needed for detection
    c. Students should be familiar with hearing tests and vision tests. *It may be possible to have the school nurse or speech pathologist come in and talk about hearing tests and how they are designed. Similarly, an ophthalmologist or optometrist could address vision tests.*

2. **Difference threshold**

    a. The minimal change in stimulation that can be reliably detected 50 percent of the time
    b. Also called the just noticeable difference (jnd)

B. **Signal-detection theory:** theory which suggests how individuals are able to detect a minimal stimulus (signal) among other background stimuli (noise). This may influence how individuals make a decision in a specific situation.

C. **Receptor sensitivity** is subject to change.

1. **Sensory adaptation:** a decline in receptor activity when stimuli are unchanging (e.g., noticing a noisy fan as one first enters a room, yet the noise seems to abate after a short time)

2. **Habituation or adaptation:** a decline in response to a stimulus due to repeated presentation of the stimulus; this happens at the neural level.

   See Activity 1.1: Sensation: Movement Detectors.

LESSON 2: Vision and Audition

OVERVIEW: This section concerns the anatomy of two important sensory systems, the visual and the auditory systems. The description of the organization of each begins with the "outermost" structures and works toward the brain. The outermost parts of the systems are designed to be sensitive to information in the environment (light and sound), to protect themselves and other sensitive structures (e.g., position of the cheekbone, eyelids, tears, ear drum position, etc.), and to be able to direct the system toward relevant stimuli—e.g., eye movements. Once the light or sound energy is initially encoded on the retina or inner ear, the remainder of the system is described by tracing the paths of the sensory neurons to higher centers in the brain.

I. Vision

A. Vision begins with light entering the eye.

1. Human **photoreceptors** in the eye are sensitive to wavelengths of light energy called the visible spectrum.

2. The **visible spectrum** ranges from red to violet.

B. Structures of the eye

1. **Sclera:** mostly "white part" of eye that provides protection and structure

2. **Cornea:** specialized, transparent portion of the sclera through which light enters

3. The **iris** is the pigmented muscle that gives the eye its color and regulates the size of the pupil. The muscles of the iris control the amount of light entering the eye.

4. **Pupil:** opening in iris

5. The **lens** is the transparent, shape-changing convex structure that focuses images on the retina. The lens must accommodate in order to focus on a specific object. The ciliary muscles relax for objects in the distance and constrict, which thickens the lens, for close items.

6. **Retina:** layer containing two types of photoreceptors—rods and cones—that transduce light energy to electrochemical energy

   See Activity 2.1: Distribution of Rods, Cones, and Color Vision in the Retina.

   a. **Rods**
      i. Located primarily in the retina's periphery
      ii. Capable of receiving light energy in low light
      iii. Not involved with color perception

b. **Cones**
    i. Concentrated in the middle of the retina in the fovea
    ii. Involved with color perception in bright light
c. Both rods and cones synapse with **bipolar cells,** which synapse with **ganglion cells,** which form the **optic nerve.**
d. The **blind spot** is where the optic nerve connects to the eye and contains neither rods nor cones.

See Activity 2.2: Blind Spot in Vision.

C. Coding information in the retina

1. A **receptive field** is an area in the retina to which a particular neuron is sensitive. Receptive fields are made up of only rod or cone receptors, which send visual signals to a ganglion cell in the retina.

2. In the retina, there are sets of receptor cells connected to ganglion cells. There are two general types of receptor cells:

    a. On-center, off-surround
    b. Off-center, on-surround
    c. Receptive fields are described by their response properties. For example, an on-center, off-surround receptive field's ganglion cell will respond maximally to light projected on the center of the field (on-center) as long as no light is projected on the surrounding region (off-surround.). The reverse is true for off-center, on-surround cells.
    d. The existence of these types of cell organization makes the visual system more sensitive to changes in amount of light—which correspondingly helps us to distinguish objects from the background.

D. Visual pathways from the eye

1. The **optic chiasm** is the junction of the two optic nerves where fibers from the nasal (i.e., side closer to the nose) sides of the two retinas cross. The nerve fibers from the peripheral (i.e., side further from the nose) sides of the two retinas do not cross to the other side of the brain. The result is that the left half of the world is represented in the right hemisphere of the brain and vice-versa.

2. **Visual cortex:** located in the occipital lobe of both hemispheres and contains the many specialized cells for visual perception

E. Color theories

1. **Young-Helmholtz trichromatic theory**

    a. The retinas contain three types of cone cells, each responding best to a particular wavelength of light. One type of cone cell responds best to short wavelengths (blue light), a second type responds best to medium wavelengths (green light), and a third type responds best to long wavelengths (red light).
    b. "Other colors" are perceived through the mixing of signals from the cones.

2. **Opponent process theory**

    a. Two-color processes, one for red versus green perception, and one for yellow versus blue perception
    b. In the thalamus, some neurons are turned on by red but off by green, for example, which helps explain afterimages. *The negative color after-image of the U.S. flag is a great demonstration of this.*

3. How we perceive color is informed by types of **color blindness.**

    a. In monochromatic color blindness, the person cannot see any color at all.
    b. In dichromatic color blindness, the person perceives only two of the three visual pigments.

F. Common problems with vision

1. **Cataracts:** clouding of the lens of the eye; affects acuity and color vision

2. **Retinopathy:** damage to the small blood vessels; begins to leak and may cause blurred vision, blind spots, or floaters

3. **Glaucoma:** fluid pressure builds up inside the eye, damaging the optic nerve; blurred vision and loss of peripheral vision

4. **Macular degeneration:** inability to see objects clearly; distorted vision and dark spots in the center of vision

5. **Hyperopia** (farsightedness): focusing the image behind the retina; difficulty in seeing objects close up

6. **Myopia** (nearsightedness): focusing the image in front of the retina; difficulty in seeing objects far away

II. Audition

A. Begins with sound entering the ear

1. **Sound** is mechanical energy typically caused by vibrating objects.

2. Vibrations produce movement of air molecules (sound waves).

3. Moving one's head helps in detecting the source of a sound.

    See Activity 2.3: Locating Sound Sources.

B. Structures

1. **Pinna:** external (visible) flap of skin and cartilage

2. **Auditory canal:** part of outer ear along with pinna, leads to tympanic membrane

3. **Tympanic membrane:** also called eardrum, separates outer ear from middle ear and vibrates with reception of sound

4. **Ossicles:** three bones in middle ear (malleus/incus/stapes or hammer/anvil/stirrup) set in motion by ear drum that transmit sound vibrations to the cochlea

5. **Cochlea:** a part of the inner ear, contains fluid and receptors

    a. **Basilar membrane:** subject to pressure changes in cochlear fluid; contains the **organ of Corti,** an organ that contains auditory sensory (hair) cells
    b. **Hair cells:** Hair cells of the organ of Corti deflected by fluid movement trigger neural impulses to the brain via the auditory nerve.

C. Characteristics of sound

1. **Frequency** corresponds to the perceptual term *pitch*. Frequency is measured in hertz (Hz).

2. **Amplitude** corresponds to the perceptual term *loudness* (volume). Amplitude is measured in decibels (dB). The decibel scale is logarithmic, so a small change in dB is actually a large change in intensity. Exposure to intense sounds can cause hearing loss. *You may want to give examples of common sounds at different dB levels as a demonstration.*

3. **Complexity** corresponds to the perceptual term *timbre* (quality). Complexity is measured by looking at the shape of the sound waveform. This can be assessed by looking at how much the sound wave deviates from a sine wave (a waveform with a variation) or by decomposing the sound into its sine wave components in Fourier analysis. For example, it is interesting to compare a tone played by a violin to the same tone played by a trumpet. They can have identical loudness and pitch but certainly will sound different.

D. Auditory theories

1. **Place theory:** Differences in pitch result from stimulation of different areas of the basilar membrane.

2. **Frequency theory:** Differences in pitch are due to rate of neural impulses traveling up the auditory nerve.

E. Hearing deficits

1. **Conductive deafness:** This is when sound waves are unable to be transferred from outer to inner ear; causes include tumors, objects in ear canal, infections, otosclerosis (genetic; degeneration of the middle ear bones). Other than treating the infection and swelling, metal bones can serve as replacements.

2. **Sensorineural deafness:** This is damage to the inner ear or auditory nerve leading to the brain. Causes include infections, genetic defects, exposure to loud noises, trauma, high blood pressure, diabetes, MS. Treatments include hearing aids and cochlear implants (electronic device implanted under the skin behind ear which bypasses damaged cells and transmits electronic signals from sounds directly to the brain).

3. **Perception and attention change** to make other incoming information more important with the lack of auditory input. For example, deaf people focus more on mouth movements and other visual inputs from the environment, which change the nature of how they process information. The same is true for deficits in the other senses.

LESSON 3: Other Senses

I. Gustation (taste)

A. Taste cells are chemical-sensitive receptors located in taste bud clusters.

1. Taste buds and papillae are located on the tongue, in the throat, and on the soft palate.

2. For a stimulus to be tasted, it must be dissolved.

B. Receptors are sensitive to five basic taste qualities:

1. Sweetness

2. Saltiness

3. Sourness

4. Bitterness

5. Umami—glutamates

Given the complexities and recent discovery of umami, its classification as a fifth taste quality is a source of current debate (for an overview of umami research, see Beauchamp, 2009).

C. Other influences on taste: Smell, touch, and temperature can influence taste. It is possible to demonstrate how the flavor of food can be changed by the food's texture or the aroma it exudes. *For example, have students taste a jelly bean or chocolate while holding their nose so they can't smell the aroma—then have them release their nose and breathe, which will enhance the flavor (always be sure to check about food allergies before introducing foods in the classroom). This type of test is also possible for foods with different textures and temperatures.*

D. Types of tasters: This is based primarily on the work of Linda Bartoshuk (e.g., Bartoshuk, Duffy, & Miller, 1994), who differentiated different types of tasters based on the density of taste buds on their tongues. Bartoshuk distinguished three types of tasters based on their sensitivity to different tastes. This can lead to a great discussion of food preferences and "picky" eaters.

1. **Non-tasters** are people who are unable to taste the chemical propylthiouracil (PROP), a bitter compound.

2. **Medium tasters** are people with an average number of taste buds; they taste the bitter PROP at an average or medium level.

3. **Supertasters** are people who are extremely sensitive to some tastes, have a high number of taste buds, and are highly sensitive to PROP; women are more likely than men to be supertasters.

II. Olfaction (smell)

A. Receptors for smell are located on the **olfactory epithelium,** a thin membrane found in the upper nasal cavity.

1. Olfactory cells carry information to the **olfactory bulb.** The olfactory bulb activates the prefrontal cortex.

2. Olfactory receptor neurons have a life cycle of about 30 days and are continually created.

3. Olfactory cells in the olfactory epithelium are stimulated by gases dissolved in the fluid covering the membrane.

4. For a stimulus to be smelled, it must be dissolved.

B. Odors or scents stimulate the olfactory epithelium.

1. Odors can evoke highly emotional memories (e.g., Herz, 2004).

2. On average, women detect odors more readily than men. Also, brain responses to odors are stronger in women than in men (Kalat, 2007).

C. **Pheromones:** same-species odors, used as a form of chemical communication

D. **Anosmia** is the loss or lack of sense of smell. Specific anosmia is the inability to smell a single chemical.

III. Somesthesis—the mechanical senses

A. **Somesthesis** refers to the mechanical senses, including kinesthesis, vestibular sensation, and the skin senses.

B. **Kinesthesis**

1. Communicates information about movement and location of body parts

2. Receptors found in joints and ligaments

C. **Vestibular sense**

1. This is also called equilibratory sense.

2. Receptors are in semicircular canals and vestibular sacs found in the inner ear.

3. This is concerned with the sense of balance and knowledge of body position.

4. The vestibular organ monitors head movements and movements of the eyes.

5. The semicircular canals are filled with a jelly-like substance lined with hair cells.

D. **Skin senses**

1. Basic skin sensations include cold, warmth, pressure, and pain.

2. Current research does not support the belief that specialized receptor cells for each of the four skin sensations exist.

E. **Touch plasticity**

When an area of the skin is used a lot, it becomes more sensitive, and the receptors actually "take over" more brain space in the corresponding sensory region of the brain. Thus, when blind people use their first two fingers for brail, it has been found that in the brain, the region of the cortex devoted to these two fingers actually spreads and takes over less-used cortex from other touch areas. Thus, physical experience changes the brain directly (this has broader connections for the influence of experience on perceptual processing and thought).

F. **Pain**

1. **Pain** (Kalat, 2007): the experience evoked by a harmful stimulus; directs our attention toward a danger and holds our attention

2. Basics of pain

    a. Pain is not triggered by one stimulus (e.g., as light does for vision), and at certain intensities other stimuli can cause pain (e.g., coolness).
    b. Pain circuit: Sensory receptors respond to potentially damaging stimuli by sending an impulse to the spinal cord, which sends the message to the brain, which interprets the signal as pain.
    c. Thicker and faster axons convey sharp pain, and thinner ones convey dull pain. These axons enter the spinal cord, where they release two neurotransmitters depending on the severity of the pain:
        i. Mild pain releases glutamate.
        ii. Severe pain releases both glutamate and Substance P, a neuromodulator.
        iii. Pain receptors can also react to chemicals.
            (1) For example, capsaicin is a chemical found in hot peppers that stimulates pain receptors.
            (2) Capsaicin also leads to insensitivity to pain.

3. Pain relief: Endorphins block the release of Substance P in the spinal cord and brain stem.

4. **Gate control theory of pain:** The brain can only focus on one pain stimulus at a time (see Melzack & Wall, 1965).

    a. Pain messages from the body travel along a set of spinal cord nerve fibers, and all other sensory messages travel along another set. These pain messages are an example of bottom-up processing.
    b. Fibers carrying pain messages have pain gates, which open during a painful experience.
    c. The non-pain fibers, however, can sometimes close the pain gates if there is competing stimulation to larger nerve fibers. This can explain how rubbing or icing can seem to help relieve pain.

5. Top-down processing can also occur during the pain experience because your brain plays an important role in whether or not you will perceive pain and how that perception will occur. For example, athletes are so focused on the competition that they often are unaware of any injuries until after they have finished competing.

6. Phantom limb pain: The person feels pain in area of amputated limb.

    a. Phantom limb sensations suggest that the brain can misinterpret spontaneous central nervous system activity that still occurs even when normal sensory input (from limbs, eyes, nose, or skin) is not there.
    b. See Melzak (1992, 1993) and Ramachandran (2007).

    See Activity 3.1: Sensory Interdependencies.

LESSON 4: PERCEPTION

OVERVIEW: Perception first involves finding and attending to a stimulus, then distinguishing the stimulus from everything else (the background) and identifying the stimulus. These steps occur so quickly and with so little effort that it takes careful study to understand how complicated it all is.

Activity 4.1: The Stroop Effect is a good example of interference, suggesting we are not always in control of what we pay attention to.

I. Attentional processes

A. **Attention:** a process in which consciousness is focused on particular stimuli

1. **Selective attention:** ability to focus on one stimulus while excluding other stimuli that are present

2. **Divided attention:** ability to respond to more than one stimulus

II. Perceptual abilities

A. **Perceptual organization:** processes that group smaller units of the perceptual world into larger units

B. **Gestalt** (German for “whole”): The whole experience is greater than the sum of the individual parts.

C. **Figure-ground perception:** tendency to organize the visual field into objects (figures) that stand apart from surroundings (ground)

D. **Gestalt principles of perceptual organization:** Gestalt psychologists believed that the world is organized around best forms—some of which are defined geometrically, such as a circle, square. Perceptual systems tend to “gravitate” toward those forms so that the resultant perception may be biased toward a particular interpretation.

1. **Law of Pragnanz**

    a. Also called the law of simplicity
    b. Tendency to see things in the simplest form

2. **Closure:** filling in missing information from the perceptual array by closing in gaps

3. **Laws of grouping**

    a. **Similarity:** grouping things on the basis of how similar they are to one another
    b. **Proximity:** grouping things on the basis of how near they are to one another

E. **Perceptual constancy**

1. **Shape constancy:** Perceived shape of an object remains constant despite changes in the shape of the retinal image of that object.

2. **Size constancy:** Perceived size of an object remains constant despite changes in the size of the retinal image of that object.

F. **Depth perception:** perceived by using a number of cues

1. **Binocular cues:** depth cues provided by both eyes

    a. **Binocular disparity:** takes account of the disparate images of each retina; a depth cue resulting from slightly different images produced by the retina of the left eye and the retina of the right eye (Blair-Broeker & Ernst, 2008)

2. **Monocular cues:** depth cues provided by one eye

    a. **Motion parallax** is the phenomenon where near objects are seen as moving more rapidly than far objects when the viewer’s head is moving.
    b. **Texture gradient** is when the texture of a surface receding in the distance changes in clarity, blurring at further distances.
    c. **Linear perspective** is produced by apparent converging of parallel lines in the distance.

d. **Interposition:** One item blocks the view of items in back of it.
e. **Relative height:** Objects higher in the perceptual field are farther away.
f. **Light and shadow:** Lighter objects appear closer.

3. An **occulomotor cue** is a depth cue based on our ability to sense the tension in our eye muscles and the position of our eyes.

    a. **Accommodation**
        i. Bulging and elongating of lens
        ii. Effective only for objects within 25 feet
    b. **Convergence** is the name of the cue that takes account of the muscle tension resulting from external eye muscles that control eye movement. Convergence is sometimes classified as a binocular cue since it requires *both* eyes.

G. **Pattern perception**

1. Also called **form perception**

2. Refers to recognition and identification of faces, words, shapes, melodies, and so on

3. Begins with specific features, such as lines, and builds a perception that provides a more complex form

    a. **Feature-analysis theory:** Patterns are identified by a step-wise perceptual and decisional analysis of their distinctive features.
    b. A **template theory** describes pattern recognition. Patterns are identified by comparing whole patterns to **mental blueprints** (templates) stored in memory until an exact match is found.

III. Perceptual illusions occur when sensory stimuli are misinterpreted; demonstrate how we typically interpret sensations.

A. **Perceptual illusions** include the Müller-Lyer illusion, the Ames room, other illusions based on Gestalt principles (e.g., closure), and other perceptual sets mentioned above.

B. Perceptual illusions demonstrate how easy it is to misinterpret sensory input. However, illusions also reveal the strategies we use to interpret sensations correctly.

The resources at the end of this Unit Lesson Plan provide some examples of cases where top-down processing can mislead us to see (or hear) things that are not actually there.

activity 1.1
sensation: movement detectors

From original TOPSS Unit Lesson Plan on *Sensation and Perception*

CONCEPT

This is an extremely effective demonstration that is well worth the time required to prepare the equipment the first time you do it. The demonstration allows students to learn about habituation; you can also use this during a discussion on the function of movement detector cells in the visual cortex and the processing of visual input.

MATERIALS

To do this demonstration, you will need a rotating disc with the spiral pattern. The easiest way to make this is to cut out Handout 1.1 (labeled “Spiral Pattern”) and glue it to a piece of cardboard. Trim the cardboard into a circle and punch a pencil through its center. By rotating the pencil as you hold it behind the disc, you can make the spiral turn at a reasonably steady rate. (A rotating disc can also be found at http://dogfeathers.com/java/spirals.html.)

INSTRUCTIONS

The demonstration involves having the students stare at the rotating disc for about a minute. Tell students to fix their gaze on the center of the spiral and to try not to let their eyes move. After a minute has passed, have students shift their gaze to your head. If you were spinning the disc so that it was spiraling inward, when students shift their gaze they will experience a dramatic illusion of your head expanding or rushing toward them. If the disc was spiraling outward, it will produce the opposite effect.

DESCRIPTION

What produces this startling illusion? Remember that the visual cortex contains specialized feature and movement detector cells that respond only to a particular type of visual input. When the disc spirals in, you are overstimulating and fatiguing the cells that are programmed to respond to this type of inward movement. When students shift their gaze and the inward movement detectors stop firing, there is a tendency for the corresponding outward movement

(activity 1.1 *continued on next page*)

detectors to start firing for a few seconds. It is this process, similar to the process that produces color afterimages in the ganglion cells of the retina, that accounts for the illusion.

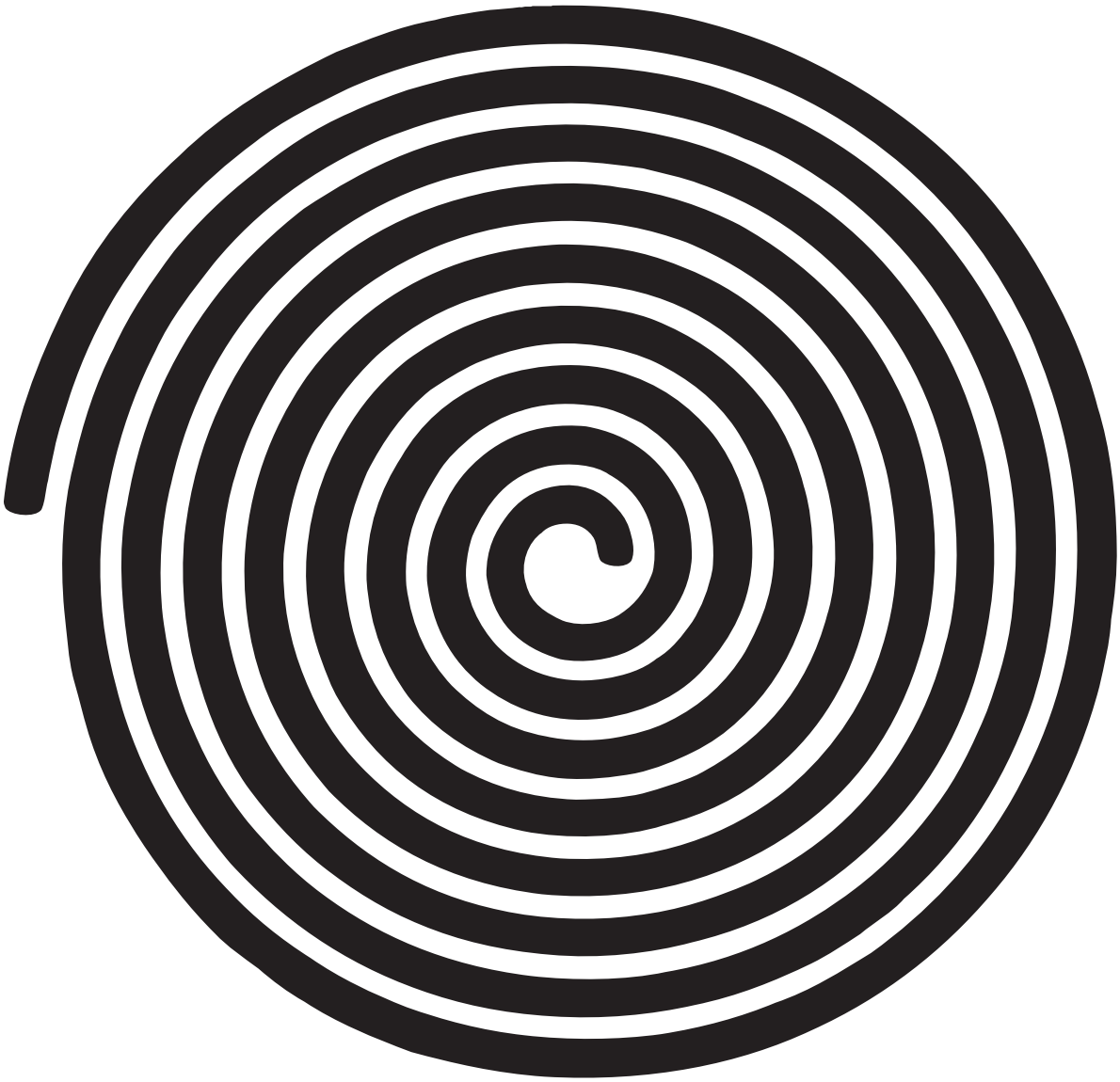
You can demonstrate that this effect takes place in the brain and not in the retina. To do this, have students view the spinning disc with one eye covered with their hand. Then, when they shift their gaze, have them also shift their hand to the other eye. The effect is visible with the left eye even though the disc was viewed with the right eye, and vice versa. This means the effect must be produced by brain cells rather than by cells in the retina. Color afterimages, on the other hand, are produced by ganglion cells located in the retina. If you try shifting eyes for a color afterimage demonstration, the effect will not appear.

This demonstration produces the most dramatic effect when students view it from straight on. Have them gather in the center of the room before you begin. It is also possible to see the effect in natural settings. If you stare at a waterfall, for example, and then shift your gaze to the trees beside the waterfall, they will appear to fly up in the air. A large faucet, such as the one in the bathtub, can be used to produce the effect as well.

This activity was prepared by Charles Blair-Broeker. Many of the ideas in this handout were taken from an exercise written by Douglas A. Bernstein and Sandra S. Goss of the University of Illinois Urbana-Champaign.

HANDOUT 1.1
spiral pattern

Cut out this spiral pattern and glue it to a piece of cardboard. Trim the cardboard into a circle and punch a pencil through its center. By rotating the pencil as you hold it behind the disc, you can make the spiral turn at a reasonably steady rate.



activity 2.1
distribution of rods, cones, and color vision in the retina

Charles T. Blair-Broker
Cedar Falls High School, IA

Douglas A. Bernstein
University of South Florida and University of Southampton

This simple activity illustrates the distribution of rods and cones in the retina and the differing ability of these photoreceptors to detect color. It can be used in classes in introductory psychology, sensation/perception, or cognition. This in-class activity takes as few as 10 minutes and can be done in any size class. It is a demonstration involving a single student but could involve greater numbers with additional time and materials.

CONCEPT

The demonstration shows that stimuli in the center of the visual field are detected mainly by color-sensitive cones concentrated in the fovea, whereas stimuli at the edges of the visual field are detected mainly by non-color-sensitive rods in the periphery of the retina.

MATERIALS

You will need a few pens, magic markers or other objects of various colors (e.g., red, blue, green, yellow, black), and a student volunteer with normal color vision.

INSTRUCTIONS

Ask your volunteer to sit or stand at the front of the room facing the class and, at your signal, to stare fixedly ahead at a spot or object at the back of the room. If the volunteer's eyes stray from the fixation point, the demonstration will probably not work very well. Emphasize the need for concentrated fixation. Instruct the class to not provide any feedback to the volunteer regarding the accuracy of his or her answers.

Now stand at the volunteer's side. Hold one of the colored objects 3 or 4 feet away from the volunteer's ear, at about eye level. (Keep the object concealed prior to this time.) Ask the volunteer to identify the color of the object in your hand. The volunteer is not likely to be able to do this. If the volunteer answers, you can determine the level of confidence by asking how much he or she would

(activity 2.1 *continued on next page*)

be willing to bet on the correctness of the answer. Move a step toward the class and slightly more in front of the volunteer (imagine you are moving on an arching track that would eventually place you directly in front of the volunteer) and ask the same question. Continue to move, one small step at a time, along the arc until the volunteer is certain of the object's color. You may want to pause before each step, briefly conceal the object, and give the volunteer a chance to relax the eyes. Make sure the volunteer is staring at the fixation point again before proceeding.

DISCUSSION

You will find that most participants have excellent peripheral vision, as reflected in their ability to recognize that the object is present even when it is far off to the side. However, for most people, it will take several small steps before they can recognize the object's color (most will first say it is black, because they are seeing it only with rods). The students will be surprised at how close to the center of the visual field the object must be before its color is clearly apparent. In real life, we perceive color in the periphery of the visual field because the brain remembers what color belongs there or makes an assumption about the likely color (e.g., the sky is usually blue). In this demonstration, however, there is no way for the brain to accurately guess the color of the object.

If the expected sequence of results does not occur, it is probably because the participant lost fixation or made a lucky guess about color. To confirm the distribution of rods and cones and their color sensitivity, you can run more trials using different colors.

You can make this demonstration an active learning experience by asking students to predict the results of this procedure and to justify their predictions on the basis of material presented in class or in the textbook. Another option is to divide the class into teams of three and have them conduct the procedure, perhaps using objects of different sizes and colors, held at differing distances. Team members can take turns acting as volunteer, experimenter, and data recorder (whose job is to note the point on each trial where the object is first detected, correctly named, and its color identified). Afterward, teams can be asked to report their results to the class, including the effect of object size and distance, and to suggest plausible explanations for the discrepant data (e.g., individual differences in retinal anatomy, restricted peripheral vision, or less fixation during a trial).

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activity 2.2
blind spot in vision

John J. Duda

CONCEPT

That area at the back of the eye where the nerve fibers from all parts of the retina collect to form the optic nerve is called the optic disc or, more commonly, the "blind spot." Indeed, that portion of the retina is functionally blind—incoming light is ineffective because there are no photoreceptors in that region. The two exercises described here provide interesting illustrations of the blind spot.

MATERIALS

Take a blank piece of white paper that measures 8½ by 11 inches and cut it in half so it is 5½ inches.

INSTRUCTIONS

On one side of the paper, center and type (or print in corresponding size) a capital X and a capital Y about 4 inches apart. On the other side, center and type capitals X, Y, and Z about 3 inches apart (with Y in the center).

For the first demonstration, hold the side of the paper with the X and Y at arm's length while covering one eye with the other hand. If the left eye is covered, fixate on the X (assuming it is on the left), and vice versa. Then slowly advance the paper toward the eye. Notice what happens to the Y: At some critical distance from the eye it disappears, but as the distance from the eye is further decreased, it reappears. You should then be able to tune the Y in and out by adjusting the distance of the paper from the eye.

The second demonstration involves using the side of the paper with the X, Y, and Z; holding it at arm's length; fixating on the Y with the left eye covered; and slowly advancing the paper toward the eye. At some critical distance from the eye, the Z will disappear. If the paper is then held at this point, it is possible to observe an unusual phenomenon: Shifting fixation to the X causes the Y to disappear and the Z to reappear. Thus, by shifting fixation back and forth between and Y and the X, you can make the Z and the Y alternately pop in and out of view.

(activity 2.2 *continued on next page*)

(activity 2.2 *continued from previous page*)

DISCUSSION

Explain that we have a blind spot in each eye, or a total of two such spots in our typical visual field. Why don't we see holes in that visual field? Partly because these holes are eliminated by eye movements that shift the parts of the visual field to different portions of the retina. In addition, our visual system tends to fill in gaps in what we see in a manner similar to the Gestalt principle of closure. As a result, we are unaware of our blind spots and require a demonstration such as the one described above to illustrate their existence.

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Duda, J. J. (1981). Blind spot in vision. In J. T. Benjamin, Jr., & K. D. Lowman (Eds.), *Activities handbook for the teaching of psychology, Volume 1*. Washington, DC: American Psychological Association.

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activity 2.3
locating sound sources

From original TOPSS Unit Lesson Plan on *Sensation and Perception*

Laura Maitland

CONCEPT

Just as we perceive depth visually as a result of slight differences in the images on each of our two retinas, we perceive stereophonic sound as a result of receiving slightly different sound messages in our two cochleas. This is because our ears are about six inches apart. A sound coming from the right will have slightly more energy and be sensed slightly sooner at the right ear than at the left ear.

MATERIALS

This works best if you have several pairs of metal crickets/clickers (obtained in the party favors sections of stationery stores) and empty paper towel or toilet paper cylinders.

INSTRUCTIONS

There are many variations of this activity. One effective way of observing how well people can locate sound sources is to divide the class into cooperative learning groups of four students each. One is the subject, two are the experimenters, the fourth is the recorder/reporter. The subject sits in a chair with the experimenters at either side of him/her. The subject is asked to listen for each click and indicate the direction the sound is coming from. The subject closes his/her eyes. In any order, the experimenters click from either side of the subject, above the subject's head, directly in front, directly in back, under the chair. The recorder writes the direction of the sound, the subject's response, and the quickness of the response. This can be repeated several times. Roles can be switched. Next, the subject uses the cylinder as an ear extension. (The roller is held with the hand as a seal between the cylinder and ear.) The same procedure is followed as without the use of the cylinder. The groups summarize and compare their observations.

DISCUSSION

Because the ear closer to the sound receives a louder stimulus, receives it before the other ear, and may perceive a wave-phase difference, sounds coming

(activity 2.3 *continued on next page*)

(activity 2.3 *continued from previous page*)

from either the left or right can be quickly located by subjects. Sounds from above, below, in front, and back are more difficult to locate. Students who cock their heads are better able to locate sounds coming from above, below, in front, or back than those who keep their heads still. When the cylinder is used, the result is similar to that of using displacement goggles with vision. The effect of the cylinder is to move the ears further from one another. Clicks directly above, below, from front or back seem closer to the ear without the extension, off-center. (If you don't have metal crickets/clickers, tapping a beaker with a pencil or snapping fingers will do. Because the crickets consistently make the same sound, they are preferable.)

activity 3.1
sensory interdependencies

George M. Diekhoff
Midwestern State University

The four demonstrations described here show how information obtained through one sensory modality shapes our experience of other sensory modalities. The sensory systems work together, not independently. This activity is appropriate for classes of any size in introductory psychology or for upper-division perception/cognition classes. Each demonstration takes about 10 minutes. Demonstrations 1 through 3 involve small groups of volunteer participants or individual volunteers who are observed by the rest of the class. Demonstration 4 involves all students.

CONCEPT

With his doctrine of specific nerve energies, Johannes Müller formalized the observation that sensory experience depends less on the nature of the physical stimulus than on the cortical project areas into which the sensory nerve terminates (Benjamin, 2007; Müller, 1842). Thus, for example, stimulation of the optic nerve with light, pressure, or electricity results in a visual experience. The existence of separate, highly specialized sensory projection areas suggests that sensory experiences would be equally separate and independent. In fact, however, the senses are less independent than one might expect. The following activities demonstrate some of the interdependencies that exist among the sensory modalities.

MATERIALS

For Demonstration 1, you will need bite-sized slices of apple and potato. For Demonstration 2, you will need four 8-ounce glasses of water (ice cold, cool, lukewarm, and hot) and 1 teaspoon of sugar. For Demonstration 3, you will need two coffee cans, one 1-lb can and one 3-lb can, filled with sand until they weigh the same. For Demonstration 4 you will need the list of vowel sounds in the Instructions section.

(activity 3.1 *continued on next page*)

(activity 3.1 *continued from previous page*)

INSTRUCTIONS

Demonstration 1—The influence of smell on taste: Have volunteer participants close their eyes and hold their noses while they are fed bite-sized slices of apple and potato in a random sequence. The participants' task is to identify what they are eating. The accuracy of their perceptions is given by the percentage of responses that are correct.

Next, repeat the procedure, but have participants breathe normally as they eat. Compare the accuracy of their taste perceptions with and without the contribution of the olfactory sense to show that the sense of smell is a major component of taste. (Always be sure to check about food allergies before introducing foods in the classroom.)

Demonstration 2—The influence of temperature on taste: The water in the four small glasses should be ice cold, cool, lukewarm, and hot, respectively. To each glass of water, add ¼ teaspoon of sugar and stir until dissolved. Have a volunteer taste each sugar solution with instructions to rank its sweetness. (Obviously, the volunteer should not know in advance that the glasses contain equal amounts of sugar.) Reflecting the influence of temperature on taste, the cool and lukewarm solutions will be perceived as being sweeter than the ice cold or hot solutions.

Demonstration 3—The influence of size on perceived weight. Tell a volunteer that you are testing his or her difference threshold for weight. Have the volunteer lift each container and select the one that feels heavier. Despite their equal weight, participants almost invariably identify the smaller container as weighing more, illustrating the size-weight illusion. The influence of visual size on perceived weight is well established. Smaller objects of a given weight are judged to be heavier than larger objects of the same weight. That is, our perception of "weight" is, in part, the perception of density (i.e., weight/size).

Demonstration 4—Auditory-visual synesthesia: Read the list of vowel sounds shown below to your class with instructions to "Imagine that each sound has its own color. Your task is to match each sound to one of the following colors: red, yellow, white, black, blue."

Vowel sounds
ah, as in mama
eh, as in let
o, as in home
oo, as in boot

In a study of 400 nonsynesthetic subjects, Lawrence Marks (1975b) found evidence for a considerable degree of "cross-translation of the sensory modalities." Tabulate your students' most frequent responses to each of the vowel sounds and compare them with Marks' results:

Vowel sounds	**Most frequent color response**
ah	red or yellow
eh	white
o	red or black
oo	blue or black

Although the extent to which individuals display synesthesia varies widely, it is sufficiently salient in the experience of enough individuals to have led to the formation of the American Synesthesia Association, Inc. (http://www.synesthesia.info)

DISCUSSION

The sensory interdependencies demonstrated in this activity illustrate two fundamental principles of perception. First, the Gestalt part–whole attitude (i.e., the whole is different from the sum of its parts) applies not just to stimulus elements within sensory modalities, but across sensory modalities as well. Stimulus elements in one modality combine interactively with those in other modalities to determine the total sensory experience. Second, synesthetic experiences in particular suggest that incoming stimulation is translated into a database that is not modality specific but to which all sensory modalities have access. Thus, an auditory experience can give rise to a visual impression because both visual and auditory systems access the same modality-nonspecific sensory database. This notion also helps explain some other interesting facts of perception, including cross-modal transfer of perceptual learning, people's ability to match intensities across sensory modality, and nonverbal infants' ability to recognize visually objects that have only been experienced previously through touch. Through the sensory-nonspecific database, information presented in one sensory modality becomes available to the other modalities.

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activity 4.1
the stroop effect

From original TOPSS Unit Lesson Plan on *Sensation and Perception*

Laura Maitland

CONCEPT

In this activity, the subject sees the name of a color printed in a different color ink than its name. Because these two pieces of information conflict, the subject experiences interference. As a result of experience, the subject usually ignores the ink color and attends to the meaning of the words. When directed to ignore the word and focus on the ink color, the subject has difficulty and may name the word instead of the ink color. This particular demonstration of interference is attributed to the work of James Stroop (1935) and is referred to as the "Stroop Effect."

MATERIALS

You may use the color version of Handout 4.1 (labeled "Interference") or the uncolored version. If you use the uncolored version, students will need brightly colored markers in blue, yellow, red, and green. An online listing can be found at http://www.apa.org/science/resources/stroop.aspx.

INSTRUCTIONS

Use either the preprinted color page labeled "Interference" in this packet or the uncolored sheet in this unit. The colored sheet can be used as a demonstration. If you use the uncolored sheet, make photocopies for the students. For homework a day or two in advance of this activity, direct students to fill in the outlines with colored markers of red, blue, green, and yellow that differ from the names of the colors written. For example, students might color one word "red" with the green marker and another word "red" with the blue marker.

For the activity students work in pairs, with one acting as the experimenter and one as the subject. The experimenter tells the subject not to say the words that are printed, but to say aloud the colors that the words are printed in, as fast as possible. The experimenter records the number of errors. Then the experimenter tells the subject to try the activity with the stimulus upside down. Ask the teams to account for the difference in the number of errors. If the students attribute the difference to practice, have the subjects and experimenters switch roles and try the activity in reverse order.

(activity 4.1 *continued on next page*)

(activity 4.1 *continued from previous page*)

DISCUSSION

Students are usually surprised at their inability to control what they pay attention to. This activity also helps them become aware of how many stimuli they usually ignore. This activity may be used in a unit on cognition and memory instead, if desired.

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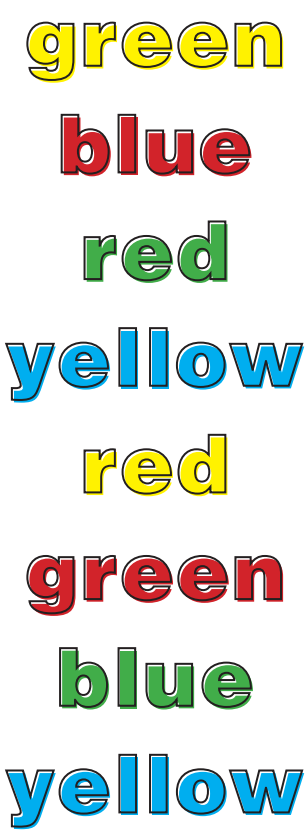
This activity was adapted from material in the American Psychological Association's former traveling psychology exhibition, Psychology: Understanding Ourselves, Understanding Each Other.

HANDOUT 4.1
interference

DON'T read the words below. Just say the colors they're printed in as fast as you can, out loud. You're in for a surprise!



If you're like most people, your first inclination was to read the words, "green, blue, red …," rather that the colors they are printed in, "yellow, red, green …"

You've just experienced **interference**.

When you look at one of the words, you see both its **color** and its **meaning**. If those two pieces of evidence are in conflict, you have to make a choice. Because experience has taught you that word meaning is more important than ink color, interference occurs when you try to pay attention only to the ink color.

The interference effect suggests you're not always in complete control of what you pay attention to.

This demonstration is called the Stroop Effect. It is based on the work of Stroop (1935).

HANDOUT 4.1
interference

green

blue

red

yellow

red

green

blue

yellow

references

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Sensory-Motor Integration. [DVD]. (1997). *The brain: Teaching modules*. Available through Annenberg Media, 1-800-LEARNER or http://www.learner.org/resources/series142.html.

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Shermer, M. (n.d.). *The pattern behind self-deception* [Video]. Available for free download at TED Talks at http://www.TED.com or http://www.ted.com/talks/lang/eng/michael_shermer_the_pattern_behind_self_deception.html

Websites

General sites

1. http://www.michaelbach.de/ot/index.html
   Eighty-four optical illusions and visual phenomena are divided into categories to make this site user-friendly.

2. http://www.bbc.co.uk/science/humanbody/body/interactives/senseschallenge/
   This is a 20-question quiz to see how much students know about their senses.

3. http://www.echalk.co.uk/amusements/OpticalIllusions/illusions.htm
   This site has more than 15 illusions that can be easily shown in a classroom.

4. http://www.skytopia.com/project/illusion/illusion.html
   This site contains some familiar illusions and some of the owner's creation. Some are animated.

5. http://homepage.mac.com/jabaro/insight_software/demo.html
   This site contains two demonstrations based on the work of John Baro.

6. http://www.skidmore.edu/~hfoley/perception.htm
   This is Foley and Matlin's website on perception, which has visuals on all aspects of perception.

7. http://www.phy.syr.edu/courses/modules/MM/n_net/n_net.html
   This website is devoted to the relationship between physics and perception.

8. http://www.exploratorium.edu
   This is the website of the Exploratorium museum in San Francisco. The website has a wealth of information on the senses and perception, many of which are interactive.

9. http://www.planetperplex.com/en/index.html
   This interactive site contains optical illusions, ambiguous images, upside down images, and impossible figures.

10. http://www.wadsworth.com/psychology_d/templates/stripped_features/try_online/tryonline.html
    Demonstrations are available including the McGurk effect, psychic phenomenon, afterimages, and some memory experiments.

Other interesting sites on sight and hearing

11. http://www.exploratorium.edu/learning_studio/cow_eye/
    This is on cow eye dissection.

12. http://webvision.med.utah.edu/
    This is on human eye anatomy.

13. http://www.iknow.net
    This CD on eye anatomy is available for purchase.

14. http://asa.aip.org/discs.html
    This CD on hearing is available for purchase.

15. http://www.gotouring.com/razzledazzle/articles/dazzle.html
    This is about camouflage in World War II.

16. http://www.ski.org/CWTyler_lab/Eyepage/index.html
    This is on vision in various species.

17. http://www.musipedia.org
    This site can generate sounds that can be useful in demonstrating pitch and loudness. (If the instructor can borrow an electric keyboard or have the music teacher help, a demonstration of the different qualities of sound can be a fun class demonstration.)

Apparent movement and movement aftereffects

18. http://www.exploratorium.edu/learning_studio/cow_eye/
    This is on cow eye dissection.

19. http://www.ritsumei.ac.jp/~akitaoka/rotate-e.html
    Try this illusion of the rotating snakes.

20. http://dogfeathers.com/java/spirals.html
    This website contains illusions and effects, some of which are animated and others in 3D.

21. http://www.lifesci.sussex.ac.uk/home/George_Mather/Motion/
    This website is devoted to different types of motion perception.

Applied topics

22. http://www.atoptics.co.uk/
    This illustrates how atmospheric conditions, such as shadows and water droplets, create natural illusions.

23. http://www.cdc.gov/niosh/mining/topics/hearingloss/hlsoundslike.htm
    This government website illustrates the effects of hearing loss with and without background noise.

24. http://www.impactlab.com/modules.php?name=News&file=article&sid=7567
    This website portrays sidewalk art that make illusion and reality difficult to distinguish.

25. http://www.safeandsoundpets.com/index.html
    Protection of the ears of pets is discussed and demonstrated here.

Lightness perception and lightness illusions

26. http://persci.mit.edu/gallery
    This MIT website contains demonstrations and explanations of such illusions as the Checker Shadow and the Munker-White.

Color aftereffects

27. http://www.cheswick.com/ches/me/
    This is an online demonstration of the McCullough effect

28. http://www.johnsadowski.com/big_spanish_castle.php
    This is a very good demonstration of color aftereffects.

Magic eye

29. http://www.magiceye.com/3dfun/stwkdisp.shtml
    This site is devoted to magic eye demonstrations.

Other Websites

Hearing Loop

http://www.hearingloop.org/

HearingLoop.org is a nonprofit informational website created and maintained by Hope College psychology professor David G. Myers and his assistant Kathryn Brownson.

Mosquito Ring Tone Website

http://www.freemosquitoringtone.org/

Download free high-frequency ring tones here (may be blocked from school computer systems).

Neuroscience for Kids
http://faculty.washington.edu/chudler/introb.html
See "Sensory Systems" for helpful information, charts, and references about the senses.

Society for the Teaching of Psychology (APA Division 2)
Office of Teaching Resources in Psychology: Sensation and Perception
http://teachpsych.org/otrp/resources/index.php?category=Sensation
Includes links to resources on "Using the Drawing and Animation Tools in PowerPoint to Build Our Own Visual Perception Demonstrations" and "Problem-Based Group Activities for a Sensation and Perception Course."

TED Talks
www.TEDtalks.com
This is a useful set of presentations of 20 or fewer minutes by noted researchers in technology, entertainment, and design. Many relate to psychology in general, but some concern basic research in perception, neurology, and applied psychology, such as the effects of noise on behavior.

Online Psychology Laboratory (OPL) Sensation and Perception Activities

The following experiments are available to teachers at http://opl.apa.org

Covert Attention
This activity presents participants with the task of pressing one of two buttons depending on where a target stimulus is located. Each trial first presents participants with either a valid or invalid cue (arrow), directing them toward or away from the stimulus they are about to see. This experiment illustrates studies done on central cues and their effect on covert attention.

Dichotic Listening
This experiment uses 15 different pairs of nonsense syllables, one played in each of the participants' two ears simultaneously. It explores dichotic listening by seeing which syllable is distinguished by the listener first in order to draw some larger conclusions about hemispheric specialization.

Line Motion
This experiment tests the strength of apparent motion by manipulating the speed with which a line moves onto the screen. Cues precede the "movement" of a line. The trials in which a false cue precedes apparent (as opposed to actual) motion demonstrate how powerful apparent motion truly is.

Lexical Decision Making
This experiment asks participants to look at different strings of letters and determine if the letters are words or non-words. Focusing on the actual structure of words, this experiment adds another variable by sometimes displaying non-words that look very similar to the words they have been paired with. This is done in order to investigate how helpful non-words can be in recognizing actual words that seem to be related to those non-words.

Müller-Lyer
This study focuses on the perception of length and the power of illusion. Using a computer program, students are asked to adjust the length of one line until they believe it is the same length as another line right next to it.

Poggendorff
This is another experiment looking at misperception and illusion. Participants are presented with two vertical parallel lines and a partial diagonal line running through them with its middle removed. This gives the illusion of a discontinuous diagonal line, despite the fact that it is actually straight. Students are given the opportunity to adjust both the length of the diagonal and the distance between the vertical lines to explore which manipulations have a greater effect on the illusion.

Ponzo
Another illusion experiment, this activity presents students with two horizontal lines a certain distance apart, either against a plain background or a background of converging lines. This second scenario creates a three-dimensional illusion. Students are asked to adjust one of the horizontal lines until they believe it is the same length as the other line. The converging-lines background creates a three-dimensional illusion and its effect on the students' accuracy is measured.

Reaction Time: Color
This experiment presents visual stimuli, such as blocks of color, and asks participants to respond by pressing a button after seeing target stimuli under three different conditions of varying complexity. Students see how their reaction time is affected by the different nature of the three tasks.

Reaction Time: Sound
This experiment presents auditory stimuli and asks participants to respond after they hear target stimuli under conditions varying in complexity. Students are made aware of each different task's effect on their reaction times.

discussion questions

1. Why are human beings sensitive only to certain types of stimuli? For example, why can't we see ultraviolet light or hear sounds that a dog can?

2. List occupations in which good vision, hearing, or other senses would be important for success. Be sure to list the reasons why. Are there occupations in which poor ability in one of the senses would be dangerous?

3. Do good readers need to use less bottom-up processing (processing the printed words) than poor readers? Why? Use examples.

4. Why do our eyes point in the same direction, yet our ears point in opposite directions?

5. Explain how an aftereffect works.

6. In neuroanatomical terms, what are the fundamental differences between sensation and perception?

7. Why do we have senses of smell and taste? What purpose do those senses serve with regard to survival?

8. Give an example of the gate theory. Why do you believe the brain reacts to pain in this fashion?

9. Which sense do you feel is the most important? Least important?

10. Why do artists, especially painters, need to understand perception? Give examples of how they use the fundamental ideas of perception.

11. What are some of the ways road signs are designed to help drivers see them accurately?

12. Can you think of occupations where excellent depth perception is required?